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AUSTRALITES FROM MULKA, LAKE EYRE REGION, SOUTH AUSTRALIA

By George Baker

Introduction

Two hundred and seventy-five specimens of markedly worn to severely worn australites from the Mulka district, via Marree, Lake Eyre region, S. Australia, have been examined in detail, and their weights and specific gravity values determined for comparison with statistically significant numbers of similar determinations for australites from other concentration centres in widely separated regions of the Australian tektite strewnfield. In addition, 414 severely worn specimens from the same area have been examined but not weighed.

Marree is approximately 25 miles from the SE. end of Lake Eyre, and is situated on the Adelaide-Oodnadatta railway line at long. 138°19′E. and lat. 29°48′S. The australies from Mulka, 130 miles NNE. from Marree, along the Birdsville stock route, come from a region of low relief and scant rainfall. The specimens have been subjected to such a degree of desert erosion that they have lost virtually all of their pre-existing surface sculpture patterns and much of their original shape and structure. Many of the specimens show the lacquer-like lustre called 'desert varnish'.

The 275 specimens for which specific gravity values have been determined are from three separate collections (1) S. R. Mitchell collection (60 specimens in N.M.V., reg. nos. E3133-3191), (2) R. D. Croll collection (51 specimens), and (3) University of Melbourne geological collection (164 specimens). All were obtained in 1930 from Mr George Aiston of Mulka, who collected them on surfaces bared by sand drift during a particularly dry period. Many were found on or around aboriginal camp sites, and have come to be regarded by some as 'magic-stones' because of aboriginal beliefs in their curative and lethal powers; no particular specimen, however, can be definitely proved to have been in use as a 'magic-stone'.

The author is indebted to the late Mr S. R. Mitchell of Frankston, Vict. to Mr R. D. Croll, of Balwyn, Vict. and to Mr Alfred A. Baker of the Geology Department, University of Melbourne, for making available the australites from Mulka for examination. The 414 non-weighed australites were inspected in the National Museum of Victoria, by courtesy of the Director, Mr J. McNally; 264 of these specimens, all with the same register number (11701), were purchased from Mr Aiston in 1935. The remaining 150 (nos. E2800-E2854, E2858-E2952) constituted part of the ethnological collection of the late Mr H. R. Balfour of Toorak, Vict., which was left to the National Museum in 1962.

Of the total of 689 australites from Mulka in the five collections examined, the better of the generally poorly preserved specimens became lodged in the Mitchell and Croll collections, and it is these only that have been used for purposes of illustration in this paper (Pls. 11-15).

Among the australites listed in private collections by Fenner (1935), 20 specimens are in the possession of Mr Aiston, and Fenner states (1935, p. 127) that

Aiston reported having 'collected and distributed many hundreds, perhaps thousands' of australites. The evidence of other collections bears this out, according to Fenner.

Proportions of shape types

The shape types of the 275 weighed australites from Mulka are listed in Table 1, and 111 of the specimens are shown in Pls. 11-15. All are worn, some being much more eroded than others, largely from sand-blasting by wind-borne sand under arid conditions, but also by other subaerial agents. Some specimens were fractured early, and subsequently worn, while some worn specimens reveal evidence of recent fragmentation which has exposed relatively fresh conchoidal fracture surfaces with secondary ripple fracture patterns and vitreous lustre. Specimens with evidence of controlled pressure flaking (Pl. 15, figs. 17-21) were prepared by aborigines.

As a consequence of relatively severe erosion, circumferential flange structures have been much chipped (Pl. 11, figs. 2-10) or completely removed. Most specimens have had the flow ridge patterns either completely erased, or so worn down that only a few reveal indistinct remnants (Pl. 11, figs. 2b, 3b, 4b, 7b, 10b, 22b). The sculpture patterns represented are entirely of tertiary origin, due to terrestrial erosion exposing and etching inner portions of these tektite glass bodies (e.g. Pl. 12, figs. 9a, b), after removal of pre-existing surfaces.

Based on the better preserved of the worn specimens and long experience, it has been possible to arrive at the grouping of specimens into the shape categories set out in Table 1 and arranged in Pls. 11-15. A few of the worst weathered and fractured specimens were not readily classifiable, and discrimination between the remnant cores of certain oval-shaped and boat-shaped specimens from Mulka (e.g. Pl. 12, figs. 5a, b, compared with Pl. 13, figs. 11a, b), had to be based on an assessment of the nature of the equatorial zone fracturing and the overall degree of erosion of each specimen, for better preserved boat-shaped forms have approximately parallel longer edges (cf. Pl. 13, figs. 13-15).

The proportions of the shape types are listed in Table 1, along with the range in weight, average weight, range in specific gravity and average specific gravity values for each shape group. In view of the degree of wear by natural processes, the weights of individual specimens are now much less than the original weights, hence those in Table 1 are minimal values.

The total weight of the specimens listed in Table 1 is 1,135.58 g, and the average weight of just over 4 g, is 1.5 times as great as the average weight (2.734 g) of 212 nearly complete to complete forms of Port Campbell australites (Baker 1956, p. 83).

After careful cleaning, each specimen was separately weighed in air and in deionized water ($T = 21.4°C$.) to the nearest 0.0005 g for determination of the specific gravity values. The results were checked and re-checked, particularly for those specimens yielding the higher and lower values. The average S.G. values determined for the various shape groups show a range (Table 1) from 2.402 to 2.455, excluding the hollow forms which have an average specific gravity of 2.060.

The differences in the average S.G. point to compositional variations among the various shape groups, and since the S.G. of tektite glass varies sympathetically with SiO_2 content, the flanged ovals are evidently the more siliceous shape types among the groups of australites from Mulka. These are followed by small oval cores, larger oval cores, aberrant 'nut-like' forms, canoes, teardrops, boats with rims and/or flange remnants, button cores and 'lenses', larger ovals, boat-shaped

TABLE 1

Shape grouping of worn australites from Mulka, S. Australia, based on the Mitchell, Croll, and Melbourne University collections

Shape type	Number of specimens	Range in weight (g)	Average weight (g)	Range in specific gravity	Average specific gravity	Percentage of shape types in combined collections	Plate and figure number
Buttons with flange remnants	26	1·190 to 5·639	3·066	2·383 to 2·486	2·439	9·5	11, 1-10
Flange fragment	1	—	0·238	—	2·428	0·4	11, 11
Button cores and 'lenses'	45	0·507 to 3·273	1·736	2·378 to 2·466	2·426	16·4	11, 12-21
Ovals with flange remnants	3	3·018 to 5·300	3·882	2·372 to 2·435	2·402	1·1	11, 22-23
Small ovals (no flange)	23	0·463 to 4·406	1·565	2·379 to 2·457	2·420	8·4	11, 24-30, and 12, 1-4
Large ovals (no flange)	2	5·007 to 19·494	12·250	2·414 to 2·441	2·428	0·7	12, 5-6
Round cores	27	1·438 to 22·645	7·158	2·397 to 2·476	2·436	9·8	12, 8-15
Oval cores	15	1·487 to 20·450	8·072	2·374 to 2·463	2·421	5·4	12, 16-18
Conical cores	6	0·565 to 7·558	3·192	2·426 to 2·460	2·447	2·2	12, 19-20
Core fragments	6	1·353 to 4·176	2·603	2·378 to 2·459	2·434	2·2	12, 21-23
Boats with rims and/or flange fragments	5	1·291 to 3·781	2·449	2·404 to 2·442	2·425	1·8	13, 1 and 3
Boat cores	55	0·983 to 22·493	5·858	2·365 to 2·474	2·430	20·0	13, 2, 4-15
Hollow forms	5	2·090 to 5·811	3·361	1·509 to 2·347	2·060	1·8	15, 1
Dumbbells, 'peanuts', and 'ladle-like' forms	27	0·894 to 8·698	4·149	2·371 to 2·474	2·431	9·8	14, 1-18
Canoes	3	1·517 to 2·674	2·005	2·400 to 2·447	2·423	1·1	14, 20-22
Teardrops	13	0·491 to 7·033	2·885	2·381 to 2·459	2·424	4·7	15, 1-10
Aberrant 'pod-like' form	1	—	5·648	—	2·431	0·4	14, 19
Aberrant 'nut-like' forms	5	1·748 to 4·974	2·775	2·401 to 2·438	2·422	1·8	15, 11-14
Nondescript fragments	2	2·023 to 2·816	2·420	2·411 to 2·437	2·424	0·7	15, 15-16
Aboriginal flakes	5	0·985 to 11·755	5·659	2·385 to 2·557	2·455	1·8	15, 17-21
TOTALS	275	0·463 to 22·645	4·129	2·365* to 2·557	2·430*	100·0	

* Excluding specimens containing internal cavities significantly affecting the specific gravity values. If the hollow specimens are included, the range in specific gravity becomes 1·509 to 2·557.

cores, dumbbells, 'peanuts' and 'ladle-like' forms, aberrant 'pod-like' form, core fragments, round cores, buttons, and finally the conical cores, in that order (aboriginal flakes omitted because from various shape groups).

From the silica—S.G. curve for tektites (Baker 1959a, p. 56), the small ovals, with the lowest average specific gravity, have a silica content of approximately 75 per cent, while the conical cores, with the highest specific gravity, have a silica content of approximately 71 per cent. The round (in plan aspect) and elongated forms of Mulka australites reveal differences in average weights, average S.G. values, and in the proportions of these two major shape groups. These relationships are shown in Table 2.

TABLE 2

Comparison of proportions, average weights, and average S.G. values of round and elongated australites from Mulka

	Number of specimens	Per cent (based on three collections)	Average weight (g)	Average S.G.
Round forms	107[a]	39	3 528	2 434
Elongated forms	168[b]	61	4 500	2 427

[a] 14 Mitchell coll., 17 Croll coll., 76 Melbourne University coll.

[b] 46 Mitchell coll., 34 Croll coll., 88 Melbourne University coll.

The round forms, having a lower average weight (Table 2), have the slightly higher average S.G. value for the Mulka australite concentration centre (excluding the obviously hollow specimens of specific gravity less than 2 350). In terms of silica content, the difference between the two average S.G. values indicates that the elongated forms are approximately 1 per cent richer in silica than the round forms.

Another feature of note is the dominance of elongate forms relative to round forms (Table 2). The reverse has been noted for 571 well-preserved specimens from Port Campbell (Baker 1955b), where 71 per cent of the australites are round forms, and 29 per cent are elongated forms. There are thus 1 6 times as many elongated as round forms at Mulka, and 2 4 times as many round forms as elongated forms at Port Campbell. This is regarded as a fundamental difference between these two australite concentration centres, and is not to be interpreted in terms of 'sampling errors' (i.e. involving differential collecting) or in terms of difference in degree of erosion (which is principally desert erosion at Mulka, and temperate zone erosion at Port Campbell). Different proportions of round and elongate australites occur within these two widely separated concentration centres, because different proportions were precipitated from the one australite shower at the time of infall. The shape populations have not been affected by the activities of aboriginal man.

Whereas only 13 per cent of the Mulka australites reveal flange remnants, 63 per cent of the australites collected by the author from the Port Campbell district are flanged. Furthermore, flanged specimens usually possess a greater volume of preserved flange glass at Port Campbell compared with Mulka. In terms of numbers only, the fact that there are nearly five times as many flanged specimens recovered from Port Campbell is a true reflection of the less severe erosion of tektite glass there, for it is doubtful that detached flange fragments (Pl. 11, fig. 11) were largely overlooked by collectors in the Mulka concentration centre. The actual volume of flange glass preserved in the Port Campbell concentration centre is more nearly 20 or 30 times as great as that at Mulka.

Distribution of S.G. values

The frequency distribution of 271 of the 275 S.G. determinations made of the Mulka australites is shown in Fig. 1, where the mode of distribution is 2·44. Four values for hollow forms, ranging from 1·509 to 2·286, are not plotted. The arithmetic mean is 2·433, but the bias in distribution is towards the higher S.G. values, as evidenced from Fig. 1, where 162 values are 2·43 and over, and 109 values are under 2·43.

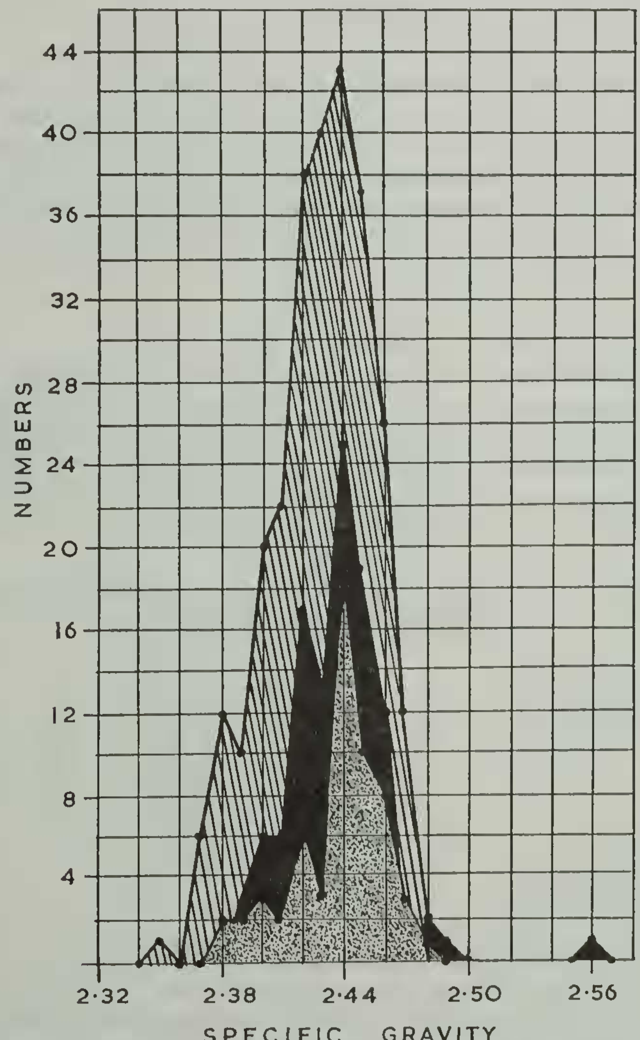

FIG. 1—Frequency polygon showing distribution of S.G. values for 271 australites from Mulka.
The S.G. values for specimens in the Mitchell coll. are represented by the stippled area, those in the Croll coll. by solid black, and those in the Melbourne University coll. by diagonal lines.

The average S.G. of approximately 1,125 g of australite tektite glass from Mulka, represented by 271 specimens (four hollow forms excluded), is approximately 2·44. By way of contrast, the average S.G. is 2·397 for a total of nearly 800 g of australite glass represented by 555 specimens from Port Campbell (Baker and Forster 1943). The difference of about 0·04 between these two averages is quite significant in terms of variation in chemical composition, inasmuch as the effects of internal cavities in each separate australite population has been minimized, as far as practicable, by not utilizing individual S.G. values under 2·350 in calculating the averages.

From the S.G.—silica curve for tektites (Baker 1959a, p. 56), the difference in the average S.G. values is found to represent nearly 4 per cent less SiO_2 in Mulka, compared with Port Campbell tektite glass. Inasmuch as (a) secondarily formed flange glass is more dominantly preserved in the Port Campbell region, and (b) flange glass generally has a lower average specific gravity value than core glass in australites, thus being more siliceous, this may partially explain the overall lower S.G. values at Port Campbell relative to Mulka (800 miles NNW.). Apart from this, there is a distinct difference in chemical composition between the two concentration centres, as evidenced by 126 core specimens from Port Campbell having a lower average S.G. value (2·408) than 156 core specimens from Mulka (average S.G. = 2·429).

Hollow forms

S.G. determinations have revealed that five of the 275 weighed australites from Mulka possess internal cavities that are not connected to the external surfaces by narrow channelways or fine capillaries. All are differently shaped forms in which the internal cavities are sufficiently large to significantly lower the S.G. value of each well below the average (2·44) for australite glass from Mulka, as shown in Table 3, where the specimens are listed according to an order of increasing S.G.

TABLE 3

Hollow australite shape types from Mulka having S.G. values significantly lower than the average of 2·44 for the tektite glass.

Shape type	S.G. value	Weight in g
1. Ball-like (button) form*	1·509	3·564
2. Lenticular form (button core)*	1·900	2·090
3. Teardrop†	2·259	3·134
4. Oval core*	2·286	2·204
5. Oval*	2·347	5·811
AVERAGE	2·060	3·361

* Melbourne University coll.
† Mitchell coll.

The total weight of these five specimens is 16·803 g.

Variability in S.G. of the five hollow forms (Table 3) can be detected in some of the specimens as due to enclosed cavities of various sizes. This is determined by holding such specimens up to a strong source of illumination, when the translucency of the australite glass in thicker parts away from the edges of the specimens, reveals the presence of a sizable internal cavity in each form. The specimens with the higher S.G. values of 2·286 and 2·347 respectively (Table 3) did not reveal the property of translucency in the thicker parts of the specimens, hence (a) the internal cavity is much smaller than in the forms with lower S.G., or (b) the absence of detectable translucency, taken in conjunction with the relatively low

S.G., indicates the presence of a number of smaller cavities scattered through the interior of the glass.

A unique specimen is the hollow ball-like form (No. 1 in Table 3), which has the largest internal cavity of all these hollow specimens. It shows remnants of a circumferential flange structure, and evidently represents a worn, distended australite button. Its external dimensions are 19 mm by 14 mm, and when held to a strong light source, the internal cavity can be approximately estimated as just under 14 mm in diameter, so that parts of the walls must be relatively thin. The specimen is lodged in the Melbourne University coll. (2685). It was purchased from Mr G. Aiston (who collected it), and later presented to Mr G. A. Ampt by Mr R. H. Croll with a view to having the pressure and composition of the gas in the internal cavity determined. This was not accomplished, and the specimen was ultimately lodged by Mr Ampt in the Melbourne University coll. in March 1934. This hollow form is only one third the size of the sliced, perfectly developed hollow australite from Horsham, Vict. (Baker 1961c). In external appearance it resembles the solid ball-like form shown in Pl. 12, figs. 7a, b, but is 2·5 mm larger.

S.G. determinations of some of the 264 Mulka specimens obtained from Mr Aiston by the National Museum of Victoria were made by Dr Dean R. Chapman and Mr Howard K. Larson of the U.S. National Aeronautics and Space Administration during their visit to Melbourne in December 1962. This revealed that two specimens were hollow, one a worn oval form, and the other a worn cylindrical form with tapered ends. On holding these specimens to a strong source of light, one of them revealed distinct, the other faint translucency. The oval form, measuring 16·1 mm long, 15·0 mm wide and 11·2 mm thick, and weighing 2·262 g, has a S.G. of 2·072. The cylindrical form, measuring 19·4 mm long, 10·8 mm wide and 10·0 mm thick, and weighing 2·433 g, has a S.G. of 2·255. Taken in conjunction with the five hollow forms listed in Table 3, the average S.G. for the seven hollow forms is 2·090 and the average weight is 3·071 g. The internal cavity in the oval form is 4 to 5 mm across and situated nearer the posterior surface. The smaller internal cavity in the cylindrical form is very close to the posterior surface.

Relationships of the Mulka concentration centre

The average S.G. of the Mulka australites fits satisfactorily into the scheme of provincial distribution of australites according to chemical composition as reflected by the trend of increasing average S.G. from SE. to NW. across the strewnfield (Summers 1909, Baker and Forster 1943). This trend is shown in Table 4 and plotted in Fig. 2, where it is seen that Mulka occupies an approximately central position relative to (a) spatial occurrence, and (b) the average S.G. range. Centres of concentration from which statistically significant numbers of S.G. determinations have been made, and the regions in which they occur, are listed in Table 4 in order of increasing S.G. The total approximate weight of the specimens listed in Table 4 is 7,000 g.

A further 185 S.G. values are available in addition to those in Table 4, but they are from approximately 40 widely scattered localities each with one to nine determinations. These have not been considered in Fig. 2, and are not included in Table 4. Only centres with over 20 determinations are included, except for Balmoral and Peake Station (Table 4), which are relatively near to other concentration centres.

Since the publication 20 years ago of considerable numbers of australite S.G. determinations, scattered parts in the Australian strewnfield (Baker and Forster

TABLE 4

Cross-continent trends of australite S.G., based on average values for statistically significant populations occurring in nine major regions

	Region	Combined concentration centres	Number of S.G. determinations	Average S.G.
A.	S. coast of W. Victoria	Port Campbell Nirranda	573 366 } 939	2·402
B.	Central part of W. Victoria	Harrow Telangatuk E.—Kanagulk—Toolondo Nurrabiel Balmoral Caramut—Kaniva—Mt. William—and other W. Victoria specimens	35 48 34 14 34 } 163	2·411
C.	E. part of S. Australia	Oakvale	24	2·417
D.	Lake Eyre, NE. part of S. Australia	Mulka William Creek Peake Station	271 96 12 } 379	2·430
E.	SW. part of S. Australia	Ooldea	28	2·434
F.	S. part of N. Territory	Charlotte Waters	29	2·439
G.	SE. part of W. Australia	Transcontinental Railway Line	24	2·441
H.	S.-Central part of W. Australia	Coolgardie—Bulong—Kalgoorlie—Norseman	52	2·443
I.	E.-Central part of W. Australia	Wingellina	135	2·460
			TOTAL = 1,773 determinations of specimens	Grand Average = 2·416

1943), many additional determinations have been made. In Table 4, 862 such are included, viz:

(a) those from Nirranda (Baker 1956), Harrow (Baker 1955a), Nurrabiel (Baker 1967), and Wingellina (Baker 1961b)

(b) most of those from Telangatuk E.—Kanagulk—Toolondo (Baker 1959b)

(c) a further 111 from Mulka

(d) several additional values for Port Campbell (Baker 1944, 1946, 1961a, 1962).

The additional values substantiate the trends established from the earlier S.G. values (Summers 1909, Baker and Forster 1943). There are other concentration centres of australites in the Australian strewnfield, but statistically significant numbers of S.G. determinations have yet to be made. The positions of the major regions and the average S.G. values for the concentration centres within those regions are shown in Fig. 2.

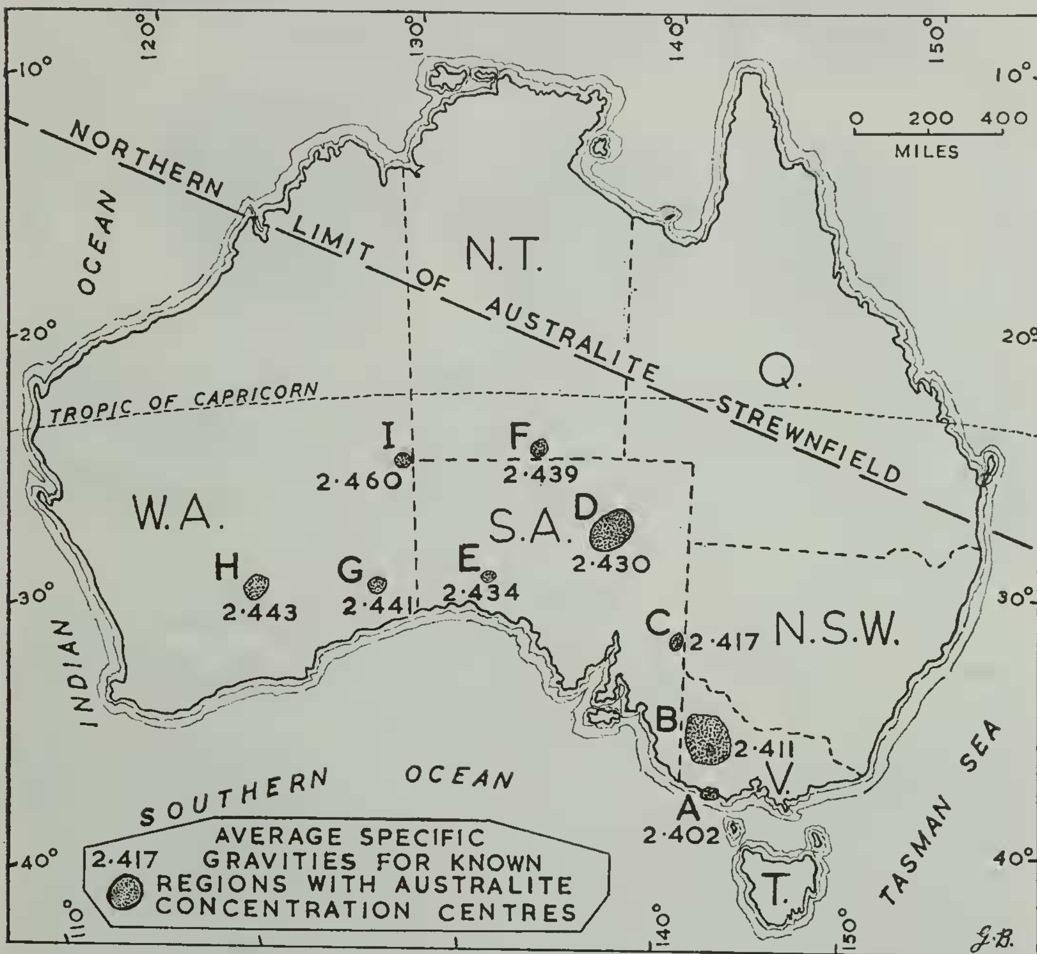

FIG. 2—Sketch map of Australia showing increase from SE. to NW. of average australite S.G. values in the concentration centres of nine widely separated regions.

A. Port Campbell—Nirranda region 939.
B. Horsham—Nurrabiel—Harrow—Telangatuk E.—Kanagulk—Toolondo—Balmoral—Caramut—Kaniva—Mt. William region 163.
C. Oakvale Station region 24.
D. Mulka—William Creek—Peake Station region 379.
E. Ooldea region 28.
F. Charlotte Waters region 29.
G. Transcontinental Line region 24.
H. Coolgardie—Bulong—Kalgoorlie—Norseman region 52.
I. Wingellina region 135.

The difference between the end members of these statistically significant average S.G. values points to a difference of some 5 to 6 per cent of SiO_2 in the average silica contents as deduced from the S.G. values. Differences in the silica contents of analyzed australites range up to approximately 11 per cent, but these are single determinations only, some of which were made about 100 years ago.

It should be noted that the known australite strewnfield extends for a further 400 miles to the SE. and a further 700 miles to the NW. The distance included between the end members of the regions shown in Fig. 2, i.e. from Port Campbell-Nirranda region in the SE., to the Wingellina region in the NW., is approximately 1,250 miles. The full range of silica variation is unlikely to be represented by the limits shown in Fig. 2. It is not yet known how much further the strewnfield extends into the Tasman Sea and Indian Ocean, so the range in silica content of end-member australites may be significantly greater than is indicated by the presently determined average S.G. values.

The distinct trend of decrease in silica content to the NW. across the continent is not consonant with the random variability in the composition of surficial geological formations. So marked a chemical distribution is not explicable in terms of the fusion of terrestrial substances. No known terrestrial process could produce such a chemical gradient. Resort is therefore made to an extraterrestrial means of distribution as adequate for producing a chemical gradient in australites across 2,500 miles of the continent. Such a gradient also calls for only one shower of australites (Baker and Forster 1943), and the fact that some specimens 'look older' than others is purely an expression of different degrees of erosion.

Special forms

Although the Mulka australites, because of their setting in an arid milieu, are relatively worn compared with specimens recovered from the more temperate regions of the strewnfield, they are in a better state of preservation than many specimens from other arid regions such as Wingellina, W.A. (Baker 1961b), Norseman, Kalgoorlie, Coolgardie and Bulong, W.A. Among them are two types of which sufficient shape and structure remain to indicate rather unusual shapes hitherto not figured in the literature. The posterior surface and side aspect of a canoe-shaped form is shown in Pl. 14, figs. 20a, b, and an enlarged silhouette tracing of the plan aspect and end-elevation are shown in Fig. 3, nos. 1, 2.

The posterior and anterior surfaces of a ridged 'nut-like' aberrant type are illustrated by two specimens shown in Pl. 15, figs. 11a, b, and 12a, b, while enlarged silhouette tracings of the end-elevations are shown in Fig. 3, nos. 3, 5, and the side-elevation of the smaller of the two specimens is shown in Fig. 3, no. 4. Two other rather more worn specimens allied to the distinctly ridged 'nut-like' forms are shown in Pl. 15, figs. 13a, b and 14a, b, but the ridges are practically all removed by weathering.

The worn canoe-shaped australite (Pl. 14, figs. 20a, b and Fig. 3, nos. 1, 2) is unusual in that it provides evidence of a type resembling Fenner's (1934 fig. 2) postulated primary form with two constrictions separating tear-shaped extremities from a larger elongated central core. All other known canoe-shaped australites reveal tapering ends (in plan) that are curved backwards (in side-elevation). This australite is the only known specimen in which the extremities spread out again beyond the two waist-like constrictions. The extremities also recurve backwards towards the posterior surface of the specimen (Pl. 14, fig. 20b), and reveal some thickening of the worn, broken ends. The radii of curvature of the posterior (R_B)

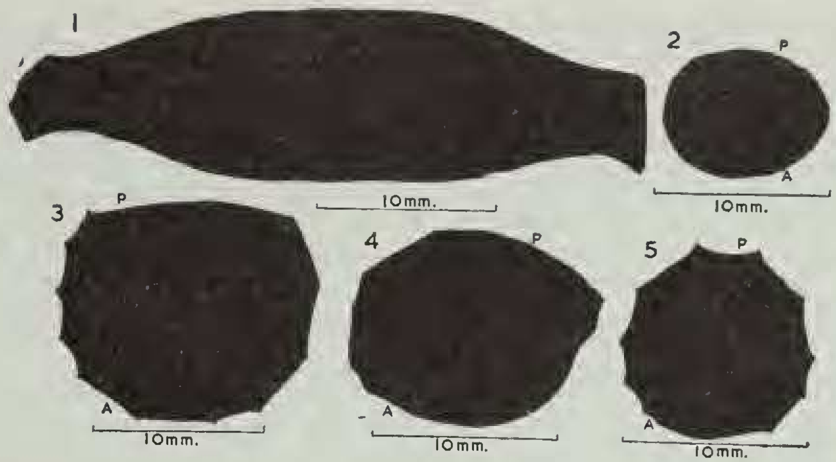

FIG. 3—Outline shapes of canoe-shaped and 'nut-like' australites from Mulka traced from enlarged silhouettes. P = posterior surface. A = anterior surface.

1. Plan aspect of canoe-shaped form showing a constricted 'waist' near each extremity (Pl. 14, fig. 20a).
2. End-elevation of canoe-shaped form depicted in no. 1 (above), showing lenticular outline comparable to a section taken normal to the long axis through its thickest portion.
3. End-elevation of 'nut-like' australite showing cross-sectional aspect of the longitudinal flow ridges revealed in Pl. 15, fig. 11b. The side-elevation silhouette reveals a small incipient flange-like process on one edge, just discernible on the posterior surface, near the top pointed extremity in Pl. 15, fig. 11a.
4. Side-elevation of smaller 'nut-like' form shown in Pl. 15, figs. 12a, b.
5. End-elevation of smaller 'nut-like' australite depicted in no. 4 (above), showing fewer flow ridge crests than the larger form in Fig. 3, no. 3.

and anterior (R_F) surfaces of this form are numerically equal, and the two arcs of curvature intersect in such a manner that the short cross section through the specimen is that of a bilaterally symmetrical lens (Fig. 3, no. 2).

Unless rounded by erosion, as in some specimens (e.g. Pl. 15, figs. 13, 14), the 'nut-like' type of australite has tapered ends and shows distinct longitudinal flow ridges that converge towards the pointed extremities (Pl. 15, fig. 11b). The specimen is evidently an entity in itself, and not a result of a peculiar type of fracturing. Comparable longitudinal flow ridges are infrequently revealed on more elongated australites like the 'pod-shaped' aberrant form illustrated in Pl. 14, figs. 19a, b. It seems possible that the 'nut-like' forms may have had a shape parentage linked with that of the 'pod-like' forms with tapered ends, and a similar secondary, but independent, atmospheric flight-shaping history.

The secondary shaping effects of such types, and their behaviour on aerodynamic heat treatment during ultrasupersonic transit through the earth's atmosphere, are debatable. Close examination of the better preserved specimens (Pl. 15, figs. 11a, b), reveals the possibility that the more extensive, slightly convex surface free from longitudinal flow ridges (Pl. 15, fig. 11a) and surface marked P in Fig. 3, no. 3, is most likely the posterior surface. The posterior surfaces of australites remained directed back along the flight path during aerodynamically stable orientation whilst high speeds of entry prevailed. For longitudinal flow ridges (of the pattern shown) to be developed from thin films of secondary melt glass (periodically produced by aerodynamical heating), it appears that the specimen would have to possess a rocking motion through the earth's atmosphere with the axis of sway passing through the pointed ends. This would be a rare and most unusual type of motion (Baker 1958).

The distribution of the longitudinal flow ridges over the anterior surfaces of the ridged 'nut-like' australites is shown by the sectional aspects through their crests in Fig. 3, nos. 3, 5. The sharpness of the crests of the ridges is over-emphasized in Fig. 3 for the purposes of illustration, and it is possible that in Fig. 3, no. 5, the specimen should have been rotated to make one surface (designated A) the posterior surface, and the other (designated P) the anterior surface. This specimen did not possess a sculpture pattern that would ordinarily provide evidence diagnostic of the posterior surface. The larger form shown in Fig. 3, no. 3 reveals the presence of an odd number (11) of longitudinal flow ridges, whilst the smaller form represented in Fig. 3, no. 5 shows an even number (10). The intervening flow troughs are slightly variable in width on the same specimen, but are rather more symmetrically disposed on the smaller one. Only half the number of flow ridges show up in the silhouette representing the side-elevation (Fig. 3, no. 4) of the smaller 'nut-like' form, and the position and distribution of the ridges in the flow pattern are not as clearly displayed. The ridges are undoubtedly remnants of a pre-existing flow pattern, and not peculiarities of terrestrial fracturing and erosion. Weathering removes them in course of time, as evidenced by the remnant 'stumps' of two longitudinal flow ridges still extant on the specimen depicted in Pl. 15, fig. 14b, and their complete erasure from another much worn 'nut-like' form shown in Pl. 15, fig. 13b. An indication that these 'nut-like' forms developed circumferential flanges, is provided by the small remnant of a flange structure on one of the specimens (Pl. 15, fig. 11a, top of photograph).

Normal forms

All of the other 270 australites from Mulka listed in Table 1 have the typical shapes characteristic of Australian tektites, but they are variously chipped, flaked, etched and worn. Features of interest are included in the descriptions of Pl. 11-15. Certain grooves and markings on some of the specimens (e.g. Pl. 11, figs. 12, 18; Pl. 13, figs. 3-4, 8, 11-12) are due to differential solution-etching effects (Baker 1961d), and are not the work of aborigines as sometimes suggested. Specimens definitely flaked and probably used as stone implements are illustrated in Pl. 15, figs. 17-21.

Variations in the sizes of the gibbosities and in the thicknesses of the waist regions of the dumbbell-shaped forms are evident in Pl. 14, figs. 1-18. Among the group of dumbbell-shaped forms, the aberrant 'peanut-like' forms were evidently subjected to considerably less ablation during high speed aerodynamic entry, for their end-elevations are approximately circular in outline, and their plan aspects and side-elevations are very similar. However, they have been worn smooth (Pl. 14, figs. 15a, b) by subaerial agencies.

Variations in the size and shape of the gibbosity in the teardrop-shaped forms, and variations in the degree of attenuation, amount of recurvature, and amount of tail-portion preserved after erosion, are shown in Pl. 15, figs. 1-10. Surface bubble craters are exposed in the tail regions of the posterior surfaces of two of the teardrop-shaped specimens (Pl. 15, figs. 8a, 10a).

The best preserved specimen, a complete flanged button illustrated in Pl. 11, figs. 1a, b, reveals so much better shape and structural characteristics compared with the rest of the specimens from Mulka, that it is likely to have come from a more temperate zone where the state of preservation is usually much better. It is in the collection of the late Mr S. R. Mitchell who acquired the 60 Mulka australites from Mr George Aiston 33 years ago. Mr Mitchell agreed that this specimen could be an extra-Mulka specimen that had become accidentally incorporated, but he was unable to suggest its origin. This complete flanged button, with excellently preserved sculpture patterns and well-developed secondary shape, is retained among the illustrations herein, in order to provide a contrast with the poorly preserved to severely weathered australites (Pls. 11 to 15) definitely known to have come from the Mulka district. The specimen measures 23·5 mm in diameter, 9·8 mm in thickness, and the width of its complete circumferential flange is 4 mm. It weighs 5·639 g, and has a S.G. value of 2·437 (T H_2O = 21·4°C.). The radius of curvature of the posterior surface (R_B) is 12·71 mm, and of the anterior surface (R_F) 13·28 mm. The original spherical (or near-spherical) form measuring 25·4 mm in diameter was ablated for a depth of 15·6 mm. This means that the original front polar regions of the primary spherical form migrated under aerodynamical heating to beyond the position of the original centre of the primary form before the process of ablation was arrested.

Silhouette tracings were made of all specimens in the Mitchell collection, and of some in the Croll collection. Radii of curvature of the posterior (R_B) and anterior (R_F) surfaces were determined graphically from these silhouettes (Baker 1955b) for several of the flanged buttons and button cores in these two collections. The details of these determinations are not presented because of the advanced state of weathering of the specimens. The results from the measurement of such worn specimens yield values over the true radius of curvature of the original posterior surface (R_B), so that the diameters of the original spherical forms, and the depths of aerodynamic ablation in the stagnation point regions, give greater values than for well preserved forms of comparable size (Table 5).

Some of the characteristics of the flanged buttons from Mulka are compared in Table 5 with those of the much better preserved specimens from Port Campbell (Baker 1962a).

TABLE 5

Comparison of some characteristics of flanged buttons from Mulka and Port Campbell

	Mulka	Port Campbell
Number of flanged australite buttons	10*	23
Average weight	3·614 g	5·297 g
Average S.G.	2·449	2·402
Average diameter	20·7 mm	22·5 mm
Average depth (= thickness)	9·3 mm	10·5 mm
Average width of flange	2·5 mm	3·5 mm
Average R_B	10·30 mm (range = 8·0 to 12·7 mm)	10·10 mm
Average R_F	11·00 mm (range = 9·8 to 11·7 mm)	12·10 mm
Average diameter of primary form	20·6 mm	20·1 mm
Average depth of ablation	11·2 mm (range = 5·5 to 16·5 mm)	9·5 mm

* 7 from Mitchell coll., 3 from Croll coll.

In Table 5, the lower values for the averages of the weight, diameter, depth, flange width, and R_F of the Mulka australites are largely a result of the chipped and eroded character of the specimens. Weathering effects have increased the calculated average values for R_B, and henee also the values for the diameter of the primary spherical form, and the depth of ablation. Because the Mulka specimens are so worn, further calculations such as the average volume loss by ablation and the average volume of the circumferential flange were not earried out. The values of these average volumes for the 23 excellently preserved Port Campbell flanged australite buttons are 44·9 per cent average volume loss by ablation of the primary form, and 15·3 per eent average volume of the eircumferential flange (Baker 1962a).

The higher average S.G. value for the flanged buttons from Mulka is significantly so much greater that the inerease cannot be attributed *in toto* to the larger volume and the better state of preservation of the Port Campbell specimens.

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Explanation of Plates

Plate 11

Mulka Australites

In all plates a = posterior surfaces, b = anterior surfaces (x 0.87).

1. Relatively well-preserved australite button showing circumferential flange and flow-lined posterior surface (1a), and anterior surface (1b) with concentric flow ridges.

2-10. Worn australite buttons with chipped flanges and solution-etched surfaces. 8a shows a worn bubble crater.

11. Worn flange fragment.
12-21. Severely worn cores of australite buttons, some with minute remnants of flanges. 12 reveals a deep solution groove, 15a shows a worn bubble crater.
22. Worn oval with circumferential flange (22a) and traces of flow ridges (22b).
23. Worn oval with chipped circumferential flange (23a).
24-30. Worn ovals.
(1-7, 12, 23-27 Mitchell collection; 8-11, 13-22, 28-30 Croll collection.)

PLATE 12

11b, is an oblique side view, and 14b, 18b, 19b, 20a are side views (x 0.87).

1-7. Worn ovals with flanges all removed by erosion. 1b shows a chipped anterior surface, 7 is a slightly oval ball-like form, 5a shows V-shaped (in sectional aspect) solution-etch grooves. The small bubble crater in 3a is 1·1 mm deep, 4b shows the remnants of a broken hollow form (top edge), the walls of which are much dulled and worn.
8-15. Worn round cores. Schlieren (i.e. flow streaks) on 8a and 10a are in the form of flow swirls, 9 is the 'indicator' type showing still attached remnants of the outer edge of the form, 11 is abraded and pitted.
16-18. Worn oval cores. 18a shows a worn bubble crater, 18b shows the worn nature of the flaked equatorial zone.
19-20. Worn conical cores.
21-23. Worn, irregular fragments of cores.
(1-4, 7, 12-15, 17, 21 Croll collection; 5, 6, 8-11, 16, 18-20, 22, 23 Mitchell collection).

PLATE 13

(x 0.87.)

1-15. Worn boat-shaped forms and boat cores. No. 1a shows remnants of the circumferential flange along the parallel longer sides of a broader form, 3-4 show deep solution grooves, 6 shows a fractured edge (left-hand side), 8a has a large, shallow crater 0·8 mm deep, 12a shows a cluster of short solution grooves, and 13-15 are smoothed by wear.
(1, 3-4, 7, 10-15 Mitchell collection; 2, 5-6, 8-9 Croll collection.)

PLATE 14

20b is a side view (x 0.87).

1-18. Worn dumbbell-shaped forms. 4 shows a slender waist, 5, 9, 14 show thick waists. 15-16 are 'peanut-like' forms, with rounded extremities in 15 and pointed extremities in the rather less weathered specimen 16. 17-18 are 'ladle-like' forms with gibbosities of different size at opposed extremities on each specimen. A flange remnant is visible along one side (right-hand side) in 1a, and is the same width in the waist region as around the gibbosities. 8 shows broader gibbosities relative to the width of the waist region, compared with other dumbbell-shaped forms. 13b shows flaked ends.
19. Worn aberrant form, cylindrical, 'pod-like' with tapered ends and indistinct longitudinal ridges on all surfaces.
20-22. Worn canoe-shaped forms. 20 shows 'splayed-out' extremities and flow streaks (brought out by natural solution-etching) trending parallel with the outline of the form.
(1-4, 9-16, 18, 20-22 Mitchell collection; 5-8, 17, 19 Croll collection.)

PLATE 15

5-6 are reversed, 17-21 are mainly fracture surfaces (x 0.87).

1-10. Worn tear-drop-shaped forms. 1 has the low S.G. of 2·259, 6 is smoothed by abrasion, 8, 10 show bubble craters 1·4 and 1·6 mm deep respectively, 10a reveals portion of a flaked equatorial zone.
11-14. Worn 'nut-like' forms. 11 shows pointed extremities and has longitudinal flow ridges relatively well-preserved, 12-14 show indistinct longitudinal flow ridges. These forms are approximately circular in end-elevation. 13, 14 are much more worn than 11, 12.
15-16. Worn, nondescript fragments.
17-21. Aboriginal flakes showing fresher fracture surfaces of artificial origin, and remnants of the worn outside surfaces. The conchoidal and subsidiary ripple fracture patterns of the glass are shown by several photographs. 19 is flaked from a round or slightly oval australite, 18, 20-21 are from distinctly oval- or boat-shaped forms.
(1-6, 11-12, 17 Mitchell collection; 7-10, 13-16, 18-21 Croll collection.)